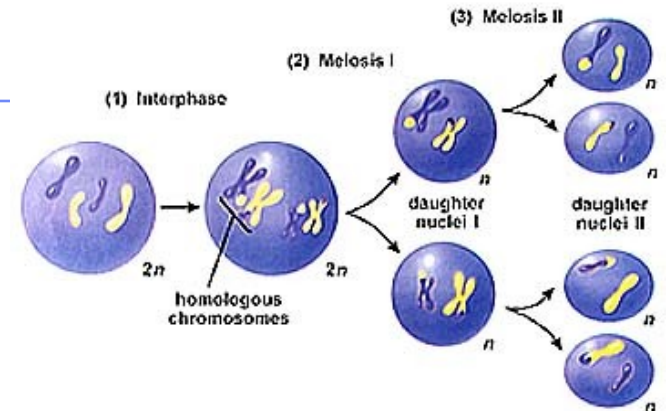
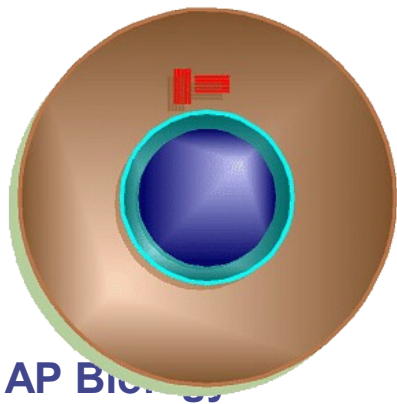
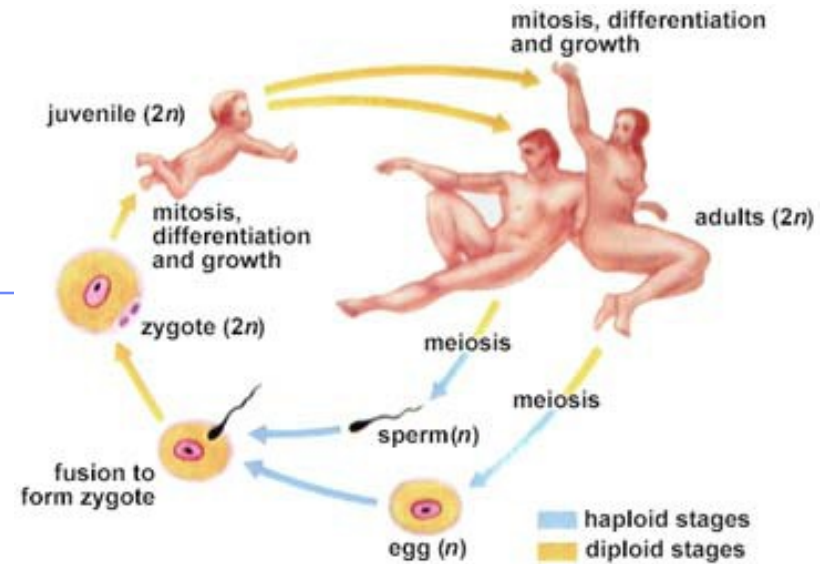


Chapter 13.

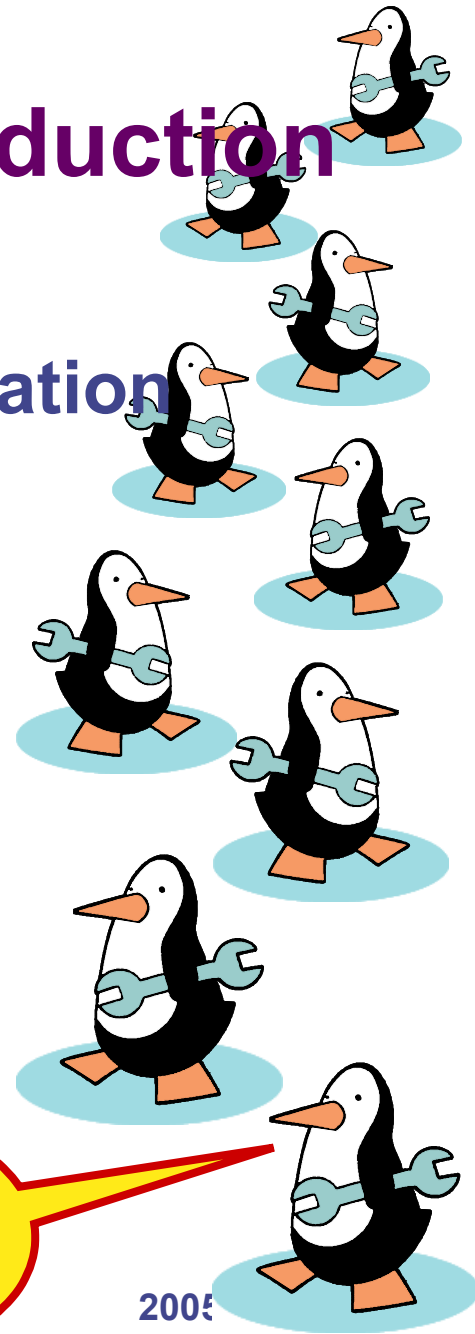
Meiosis & Sexual Reproduction



Cell division / Asexual reproduction

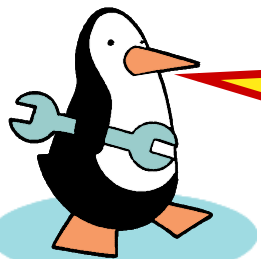
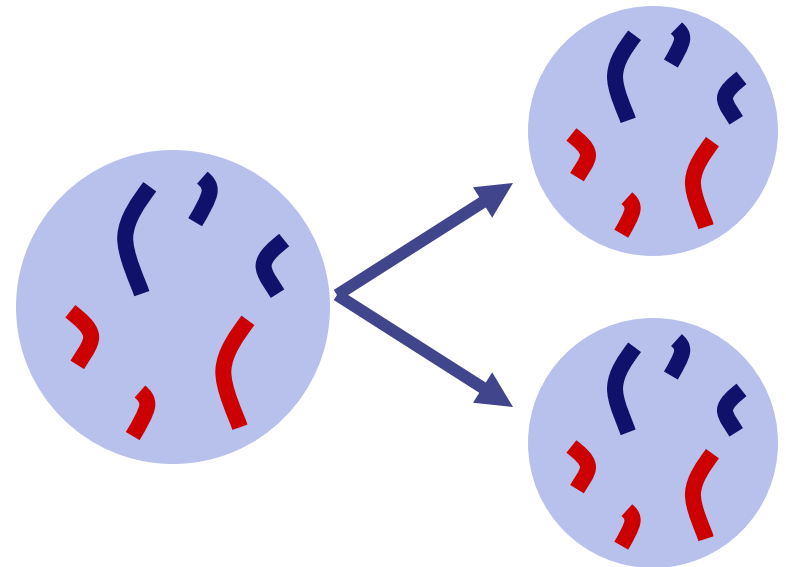
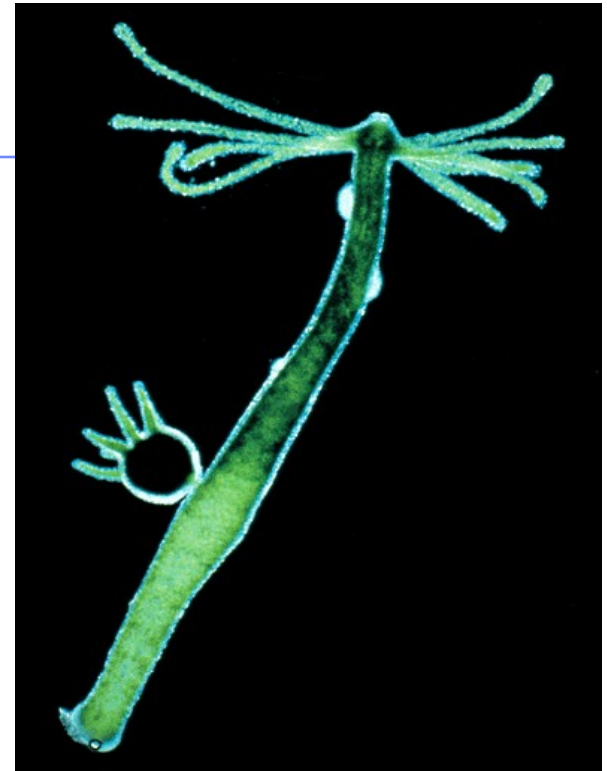
■ Mitosis

- ◆ produce cells with same information
 - identical daughter cells
- ◆ exact copies
 - clones
- ◆ same amount of DNA
 - same number of chromosomes
 - same genetic information



Asexual reproduction

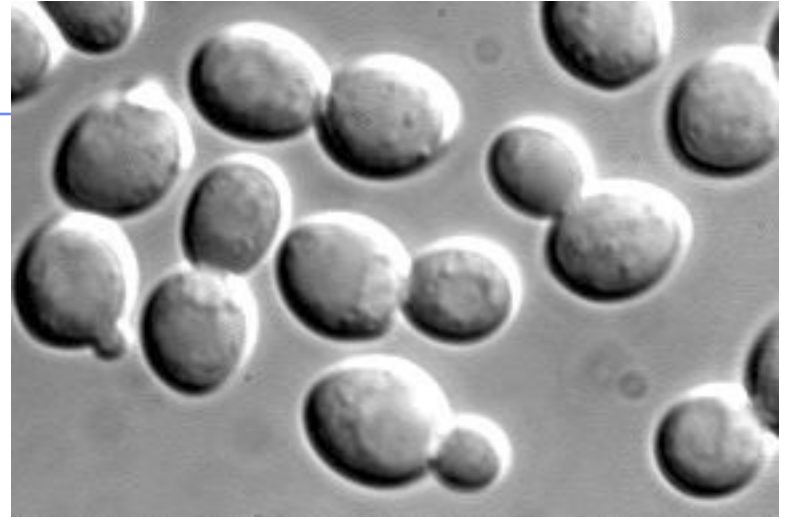
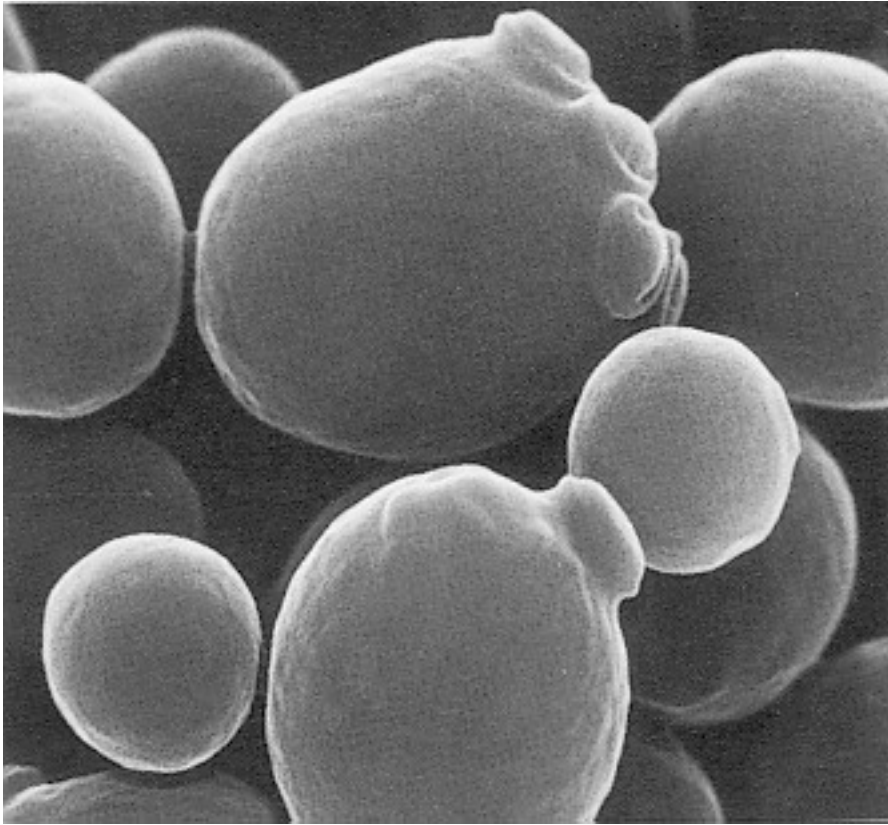
- Single-celled eukaryotes reproduce asexually
 - ◆ yeast
 - ◆ *Paramecium*
 - ◆ *Amoeba*
- Simple multicellular eukaryotes reproduce asexually
 - ◆ *Hydra*
 - budding



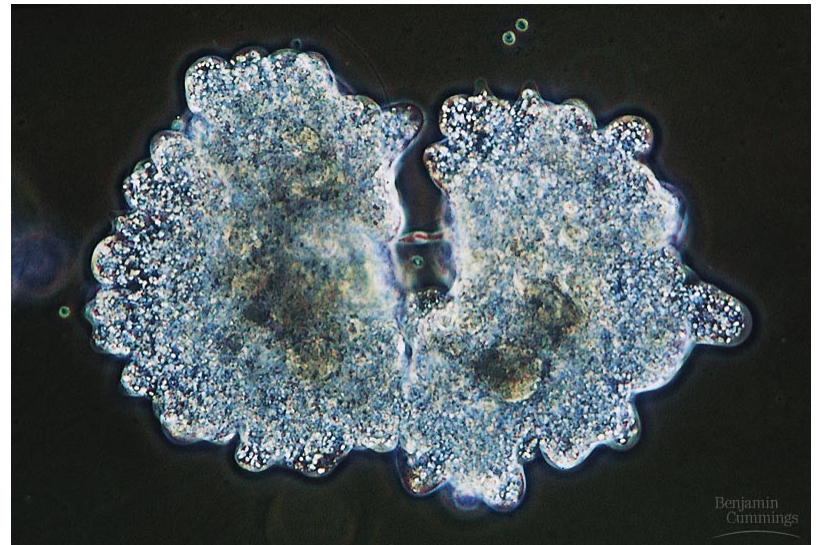
What are the disadvantages of asexual reproduction?

What are the advantages?

Budding in Yeast

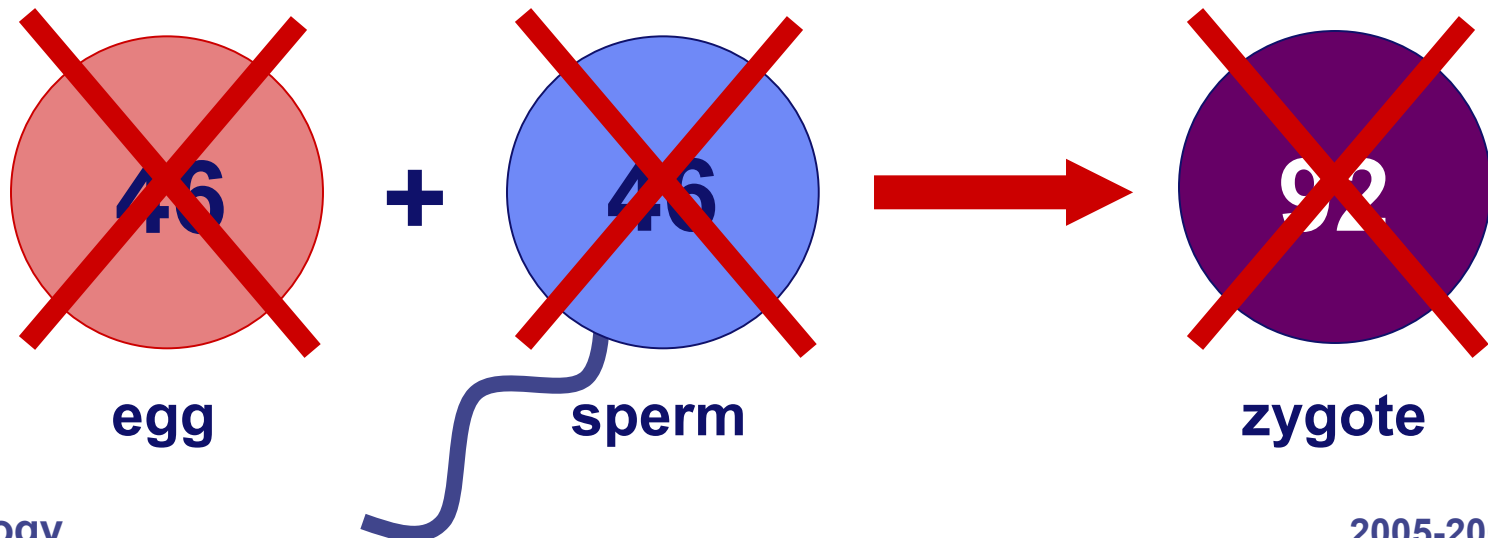


Binary fission in Amoeba



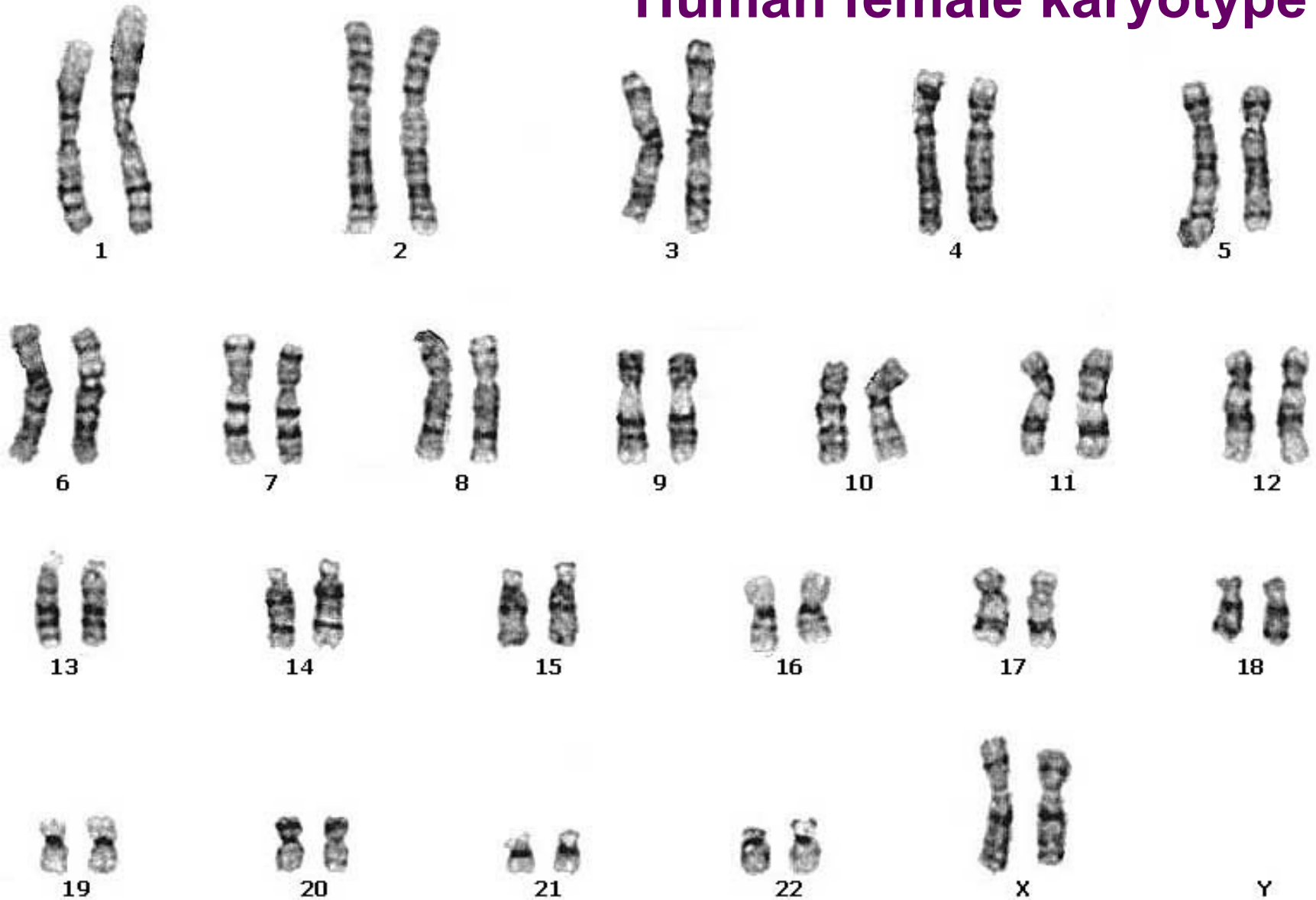
How about the rest of us?

- What if a complex multicellular organism (like us) wants to reproduce?
 - ◆ joining of egg + sperm
- Do we make egg & sperm by mitosis?



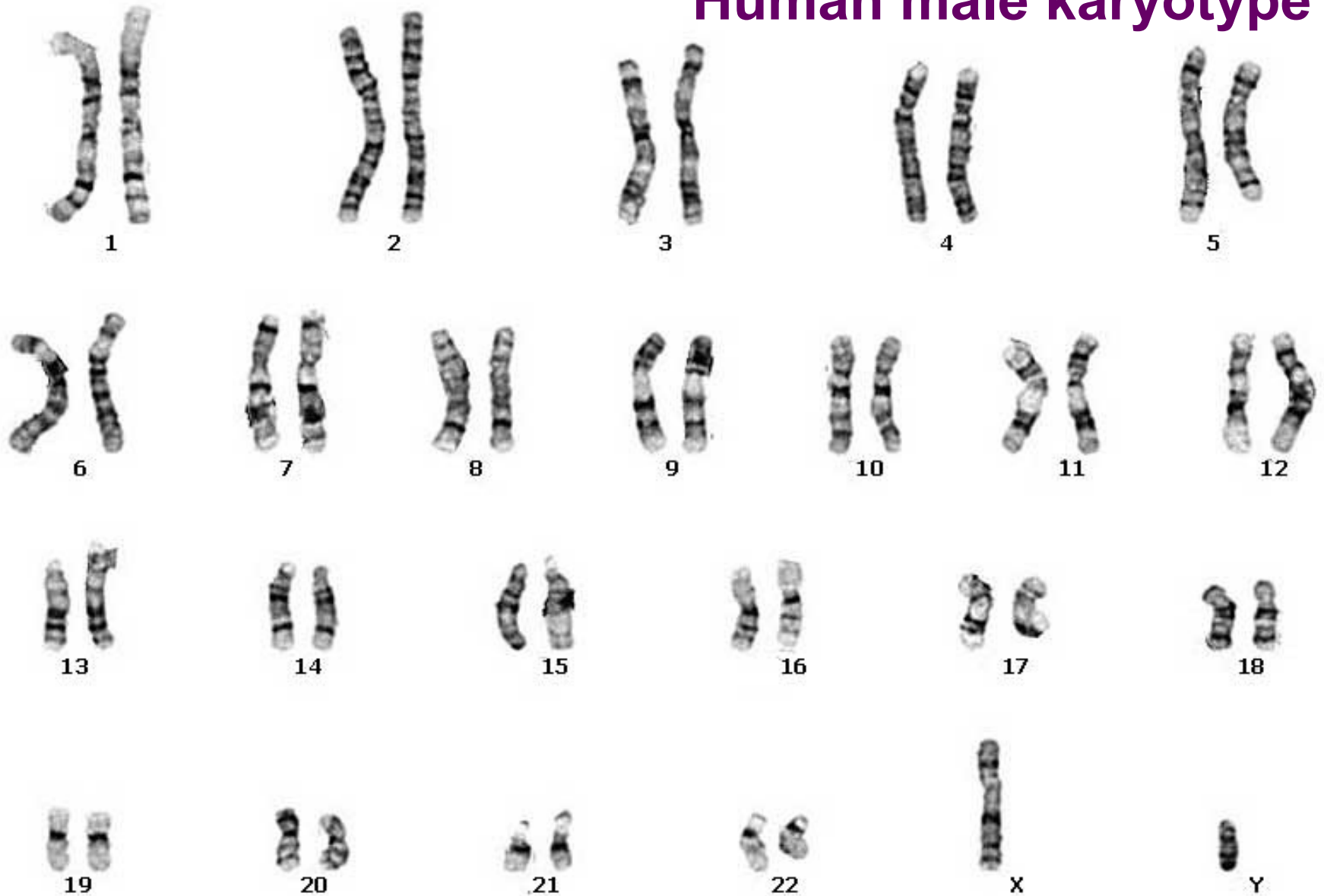
Human Female
G-bands

Human female karyotype



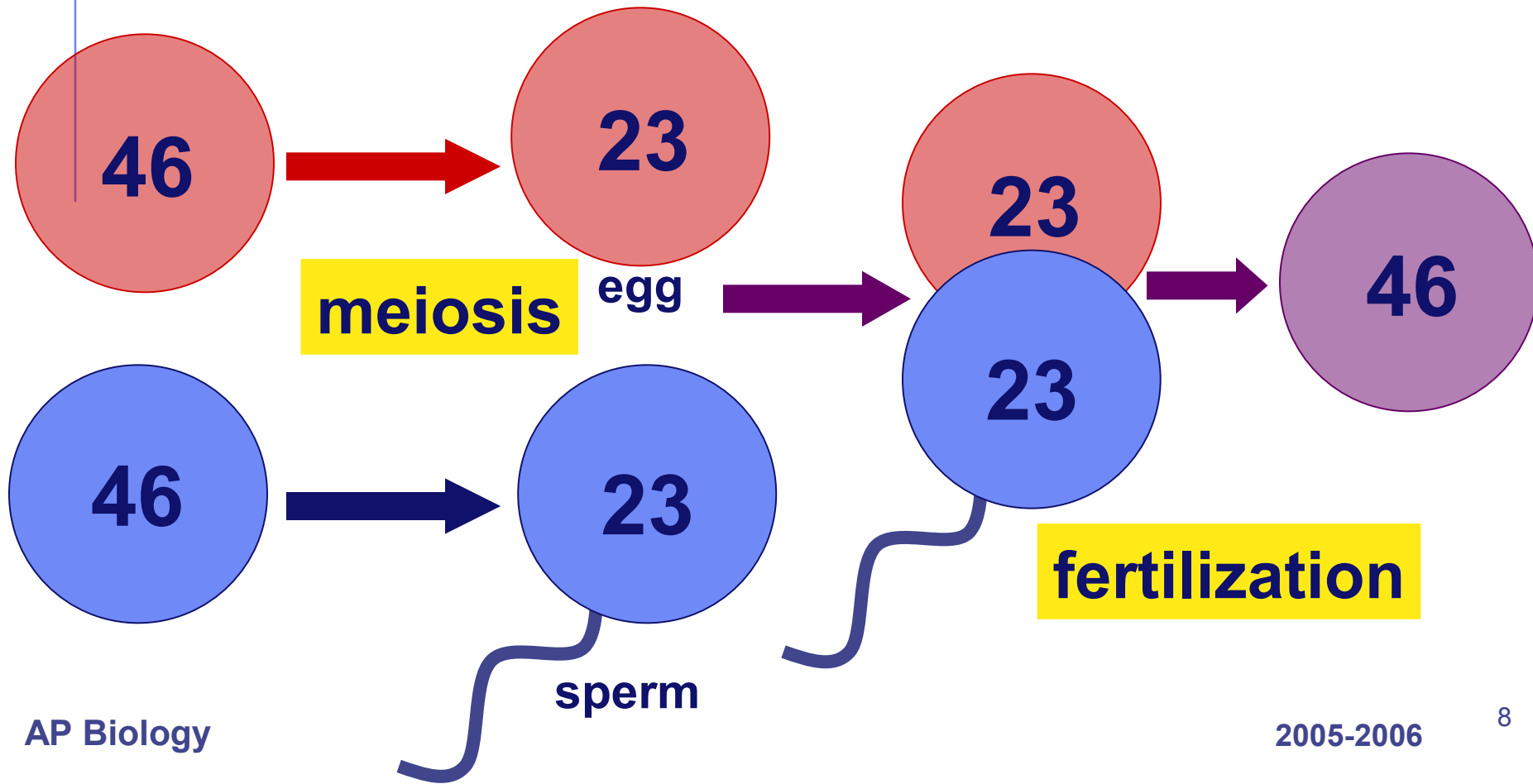
Human male
G-bands

Human male karyotype



How do we make sperm & eggs?

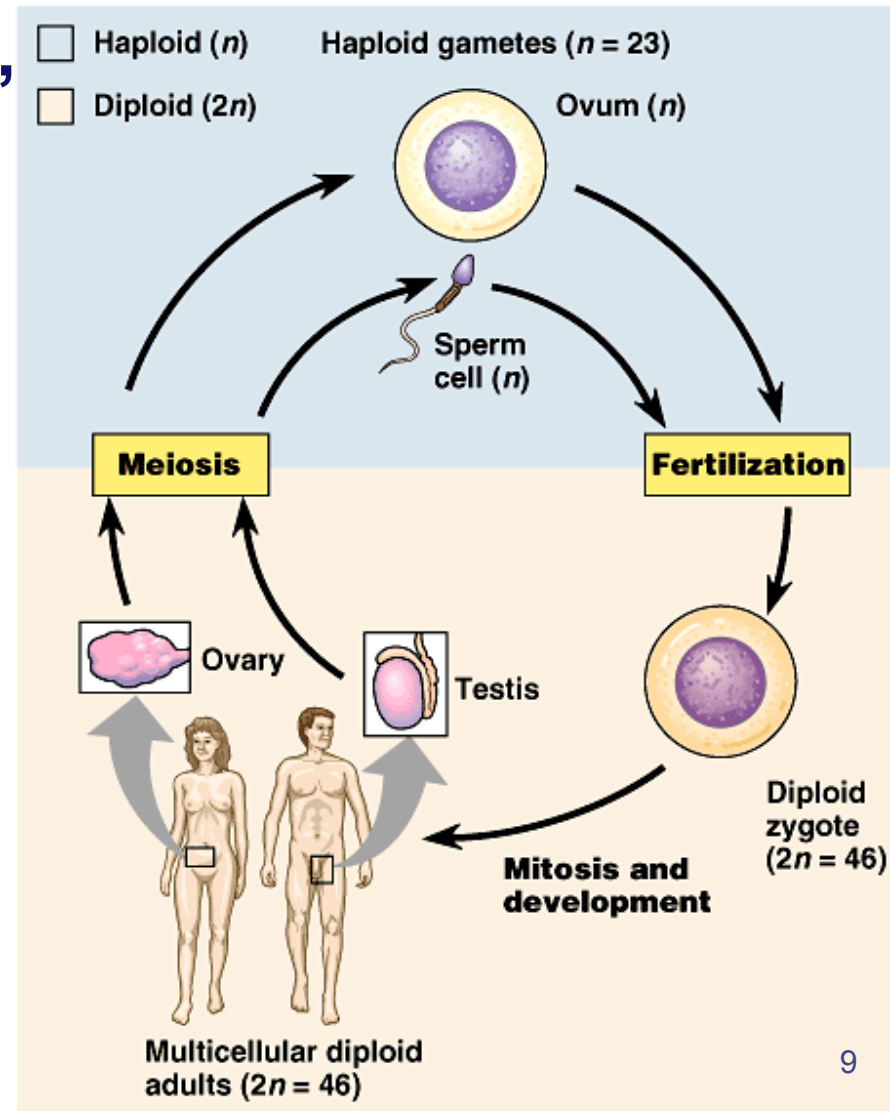
- reduce 46 chromosomes → 23 chromosomes
 - ♦ half the number of chromosomes



Meiosis: production of gametes

■ Alternating processes, alternating stages

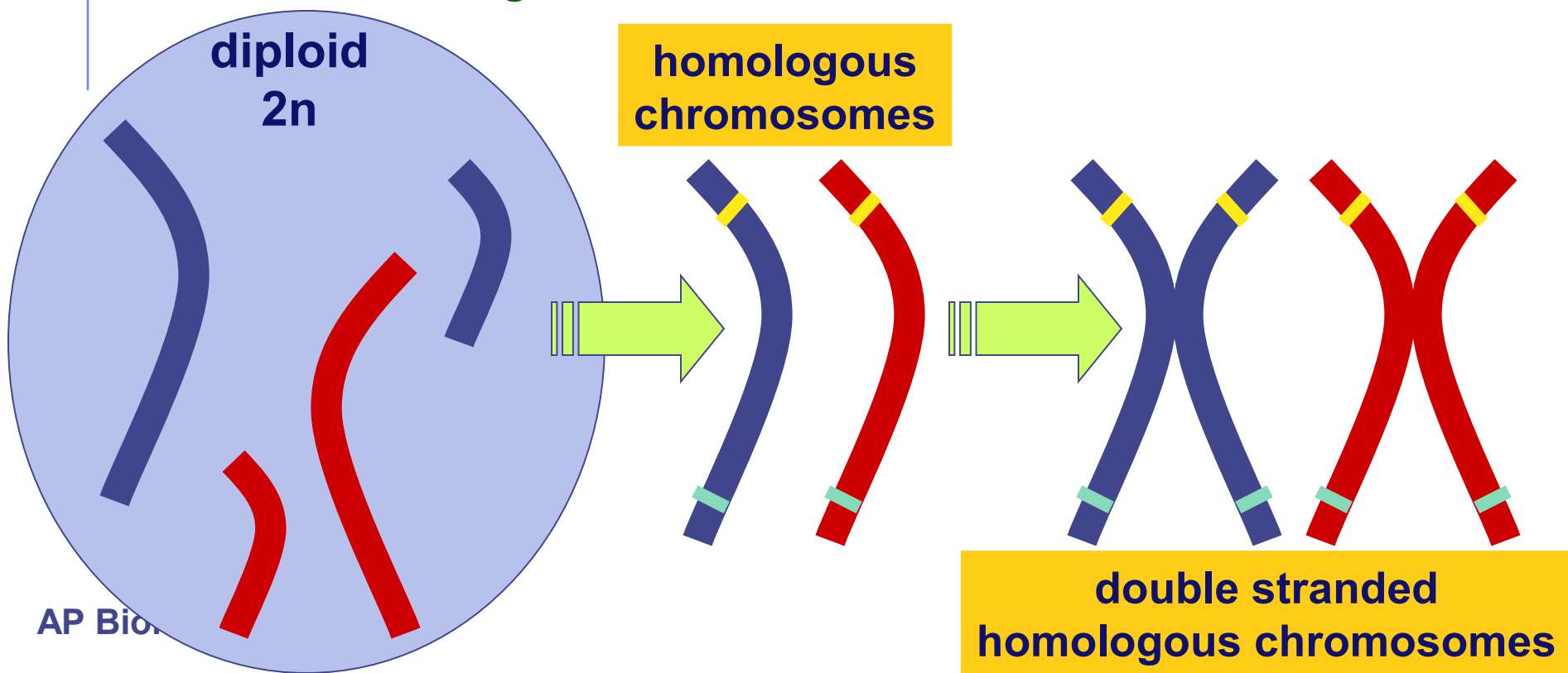
- ◆ chromosome number must be reduced
 - diploid \rightarrow haploid
 - $2n \rightarrow n$
 - ◆ humans: $46 \rightarrow 23$
 - **meiosis** reduces chromosome number
- ◆ **fertilization** restores chromosome number
 - haploid \rightarrow diploid
 - $n \rightarrow 2n$



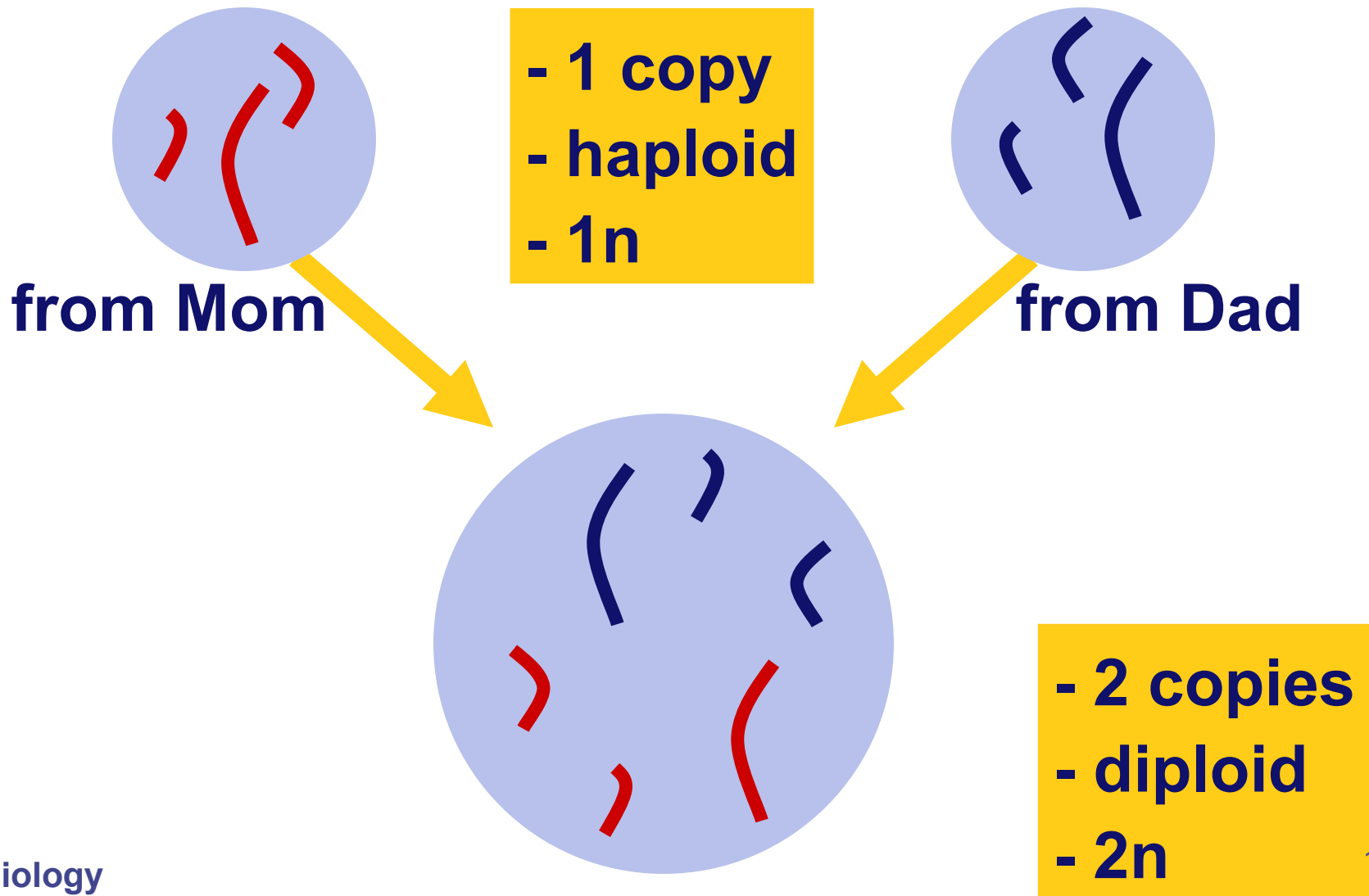
Homologous chromosomes

- Paired chromosomes

- ◆ both chromosomes of a pair carry genes
 - control same inherited characters
 - **homologous** = **same** **information**

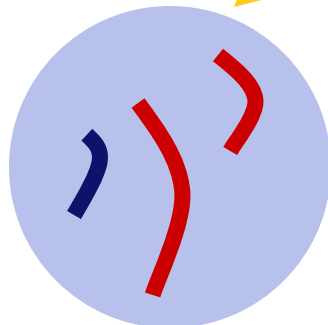
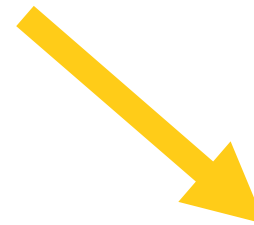
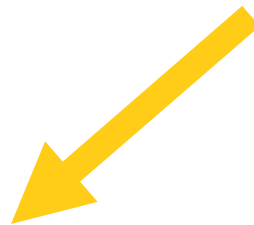
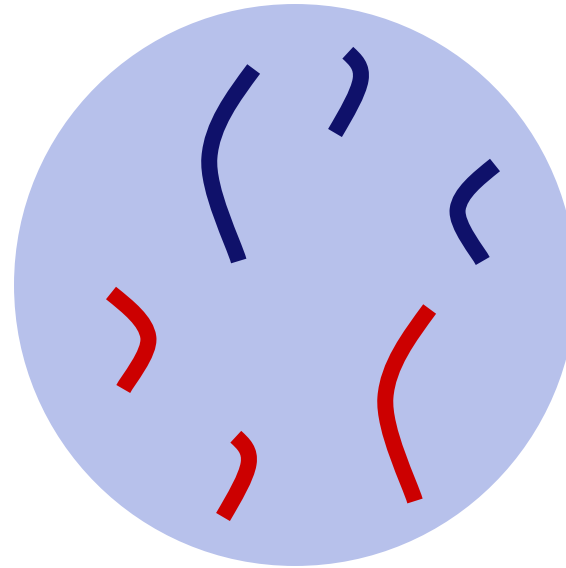


Sexual reproduction: Fertilization

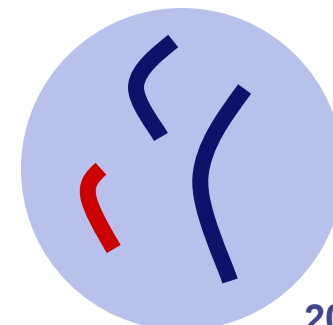


Making gametes for the next generation

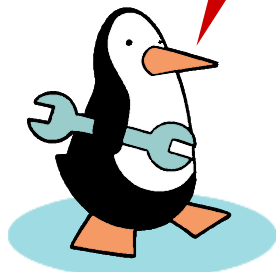
- 2 copies
- diploid
- $2n$



- 1 copy
- haploid
- $1n$



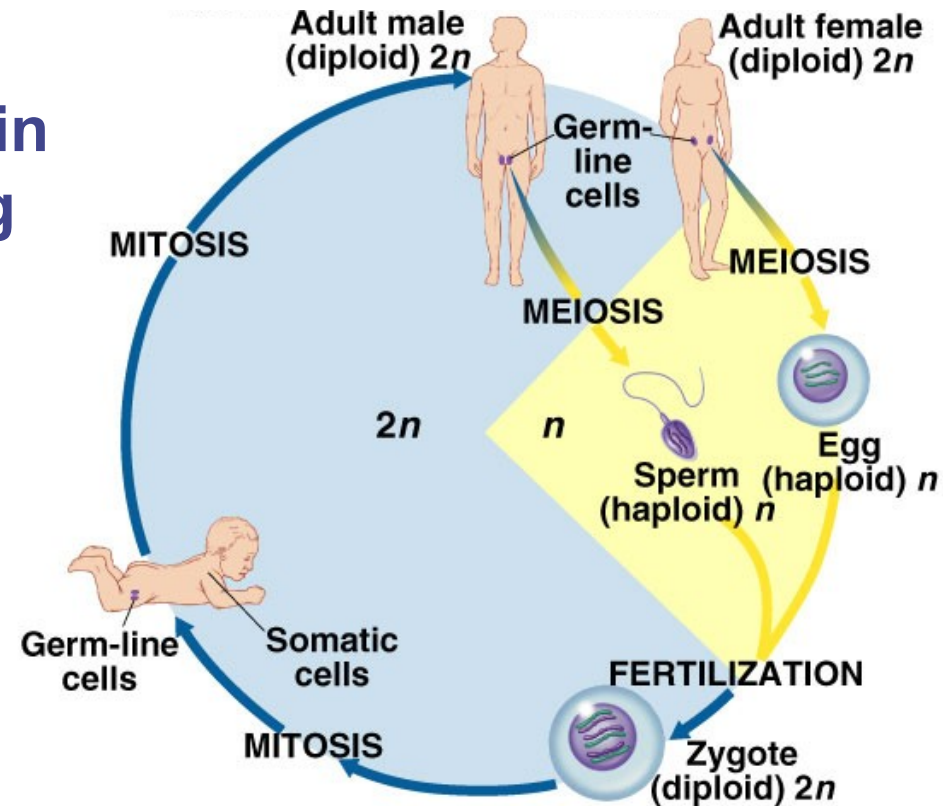
We're
mixing things
up here!



Meiosis = reduction division

■ Meiosis

- ◆ special cell division in sexually reproducing organisms
- ◆ reduce $2n \rightarrow 1n$
- ◆ diploid \rightarrow haploid
 - half
- ◆ makes gametes
 - sperm, eggs



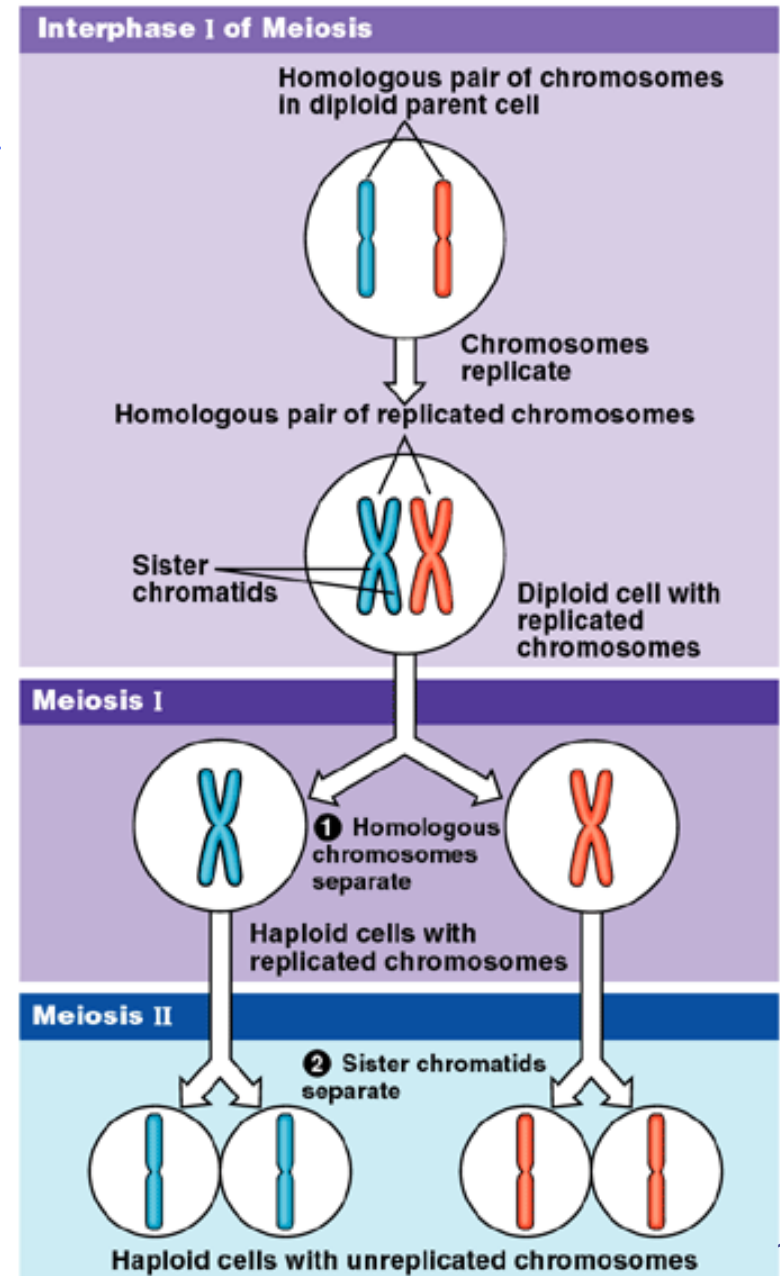
Warning: meiosis evolved from mitosis, so stages & “machinery” are similar but the processes are radically different. Do not confuse the two!

Double division of meiosis

DNA replication

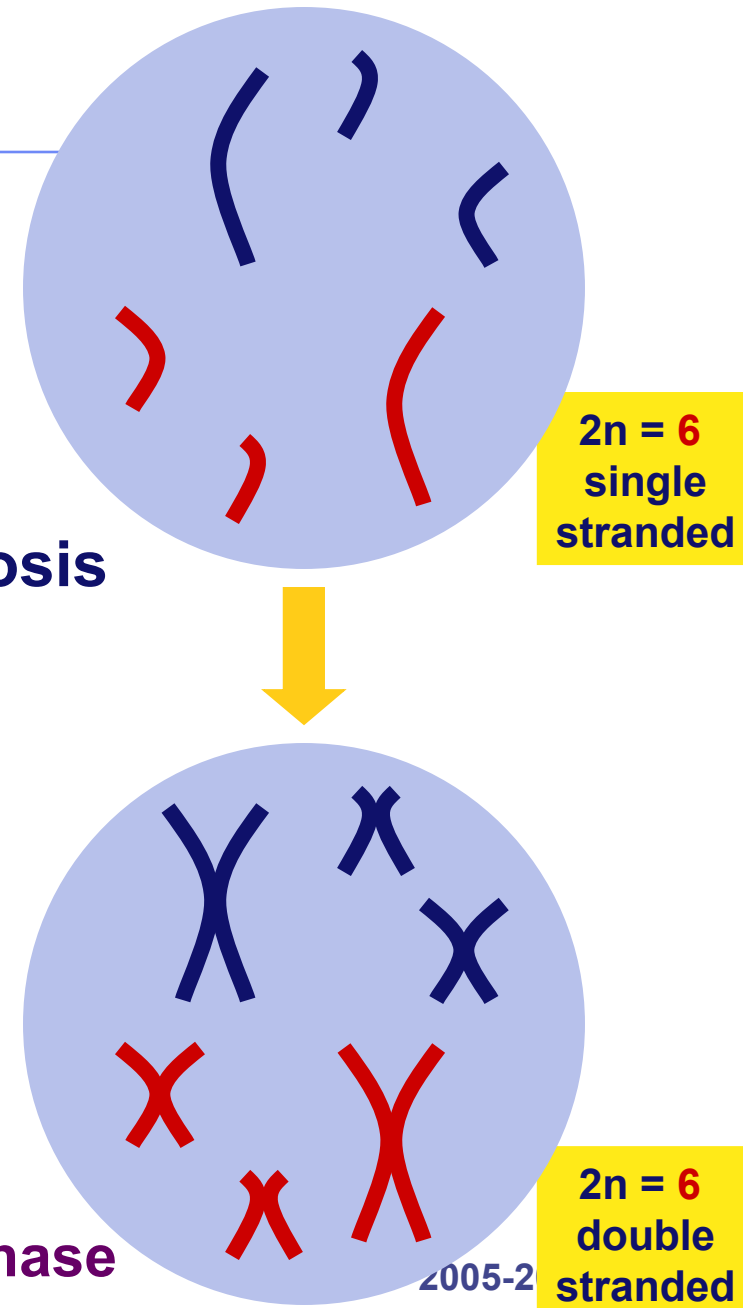
1st division of meiosis separates homologous pairs

2nd division of meiosis separates sister chromatids



Preparing for meiosis

- 1st step of meiosis
 - ◆ Duplication of DNA
 - ◆ Why bother?
 - meiosis evolved after mitosis
 - convenient to use “machinery” of mitosis
 - DNA replicated in S phase of **interphase** of **MEIOSIS** (just like in mitosis)



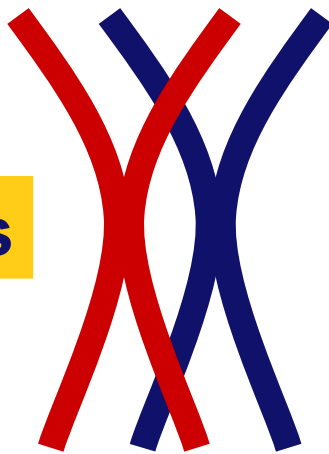
M1 prophase

2005-2

Preparing for meiosis

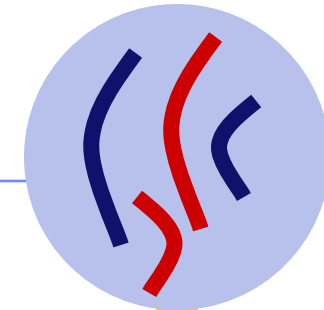
- **1st division of meiosis separates homologous pairs**

synapsis

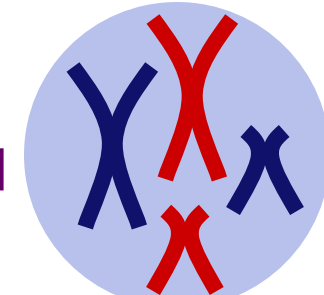


tetrad

prophase1

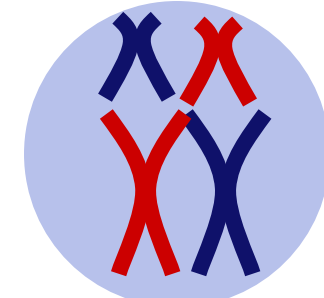


**$2n = 4$
single
stranded**



**$2n = 4$
double
stranded**

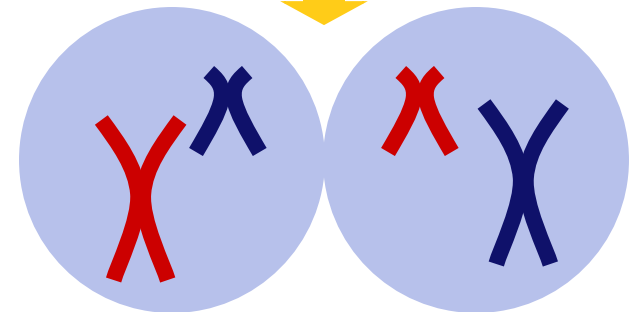
metaphase1



**$2n = 4$
double
stranded**

telophase1

**$1n = 2$
double
stranded**



Meiosis 2

- **2nd division of meiosis separates sister chromatids**

1n = 2
double
stranded

What does
this division
look like?

1n = 2
double
stranded

prophase2

metaphase2

1n = 2
single
stranded

telophase2

2005

17

Steps of meiosis

■ Meiosis 1

- ◆ interphase
- ◆ prophase 1
- ◆ metaphase 1
- ◆ anaphase 1
- ◆ telophase 1

■ Meiosis 2

- ◆ prophase 2
- ◆ metaphase 2
- ◆ anaphase 2
- ◆ telophase 2

**1st division of
meiosis separates
homologous pairs
($2n \rightarrow 1n$)**

**2nd division of
meiosis separates
sister chromatids
($1n \rightarrow 1n$)
* just like mitosis ***

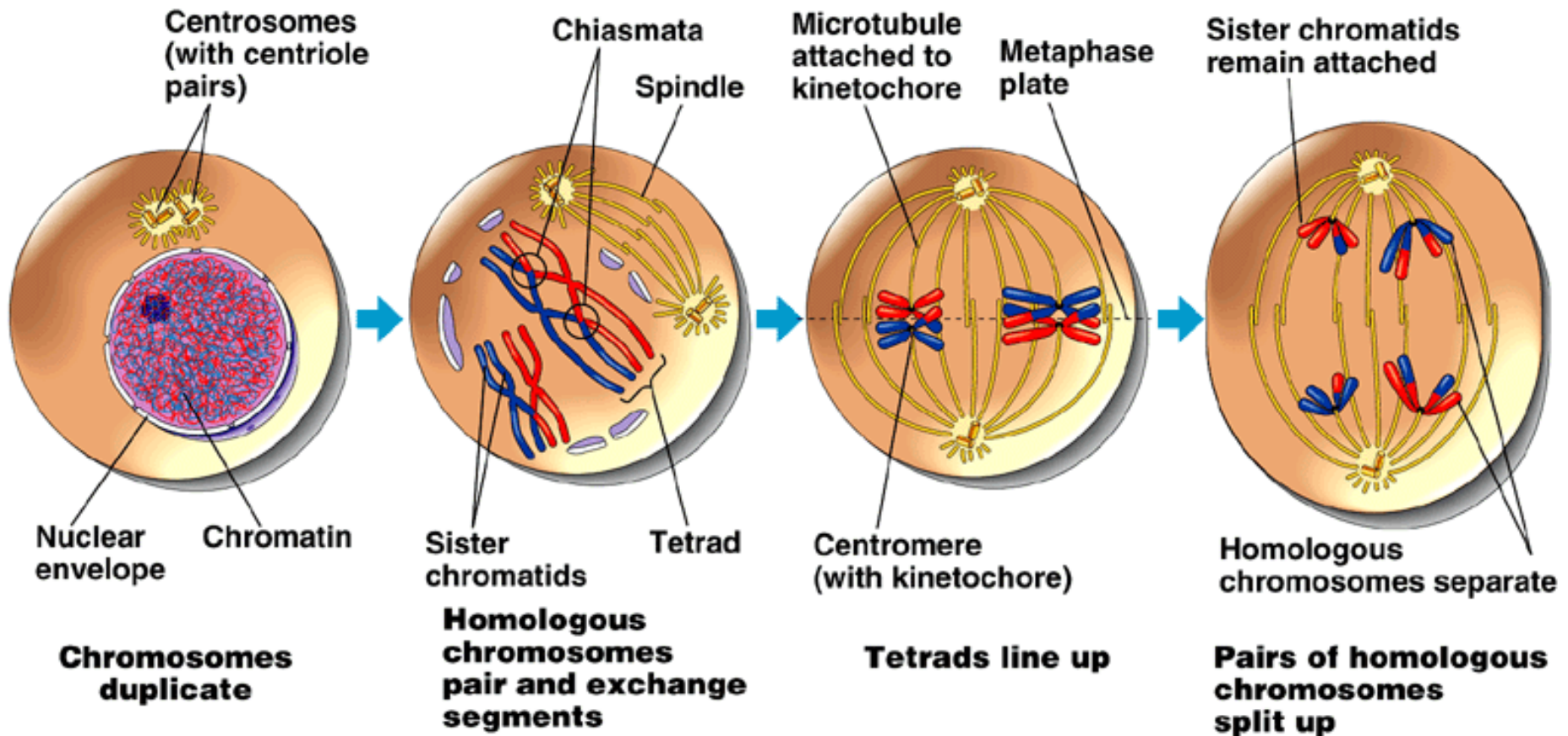
MEIOSIS I:
Separates homologous chromosomes

INTERPHASE

PROPHASE I

METAPHASE I

ANAPHASE I



MEIOSIS II:
Separates sister chromatids

**TELOPHASE I
AND CYTOKINESIS**

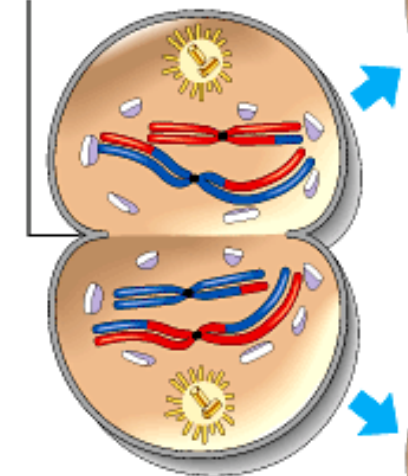
PROPHASE II

METAPHASE II

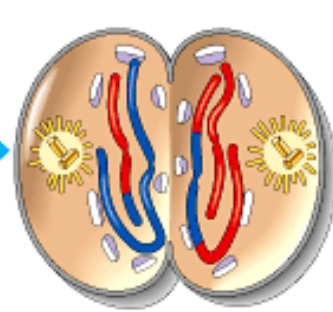
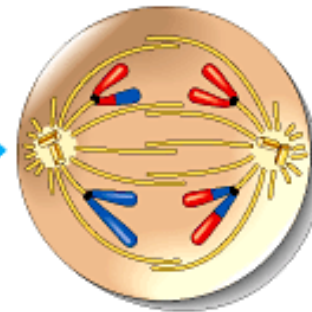
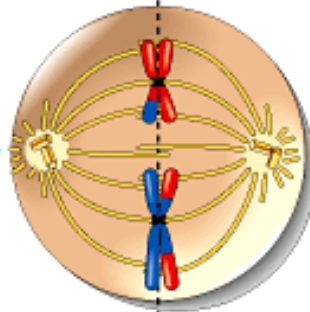
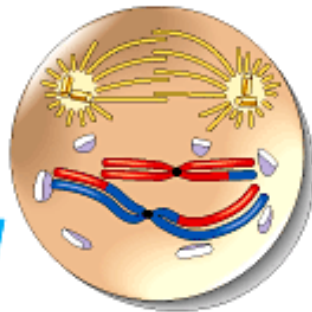
ANAPHASE II

**TELOPHASE II
AND CYTOKINESIS**

Cleavage
furrow

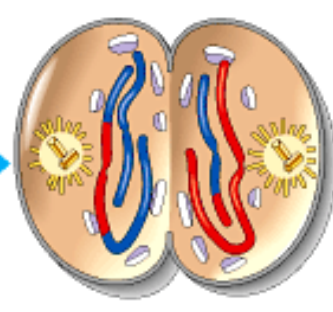
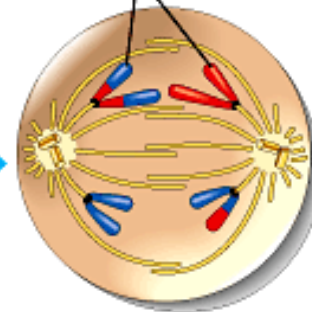
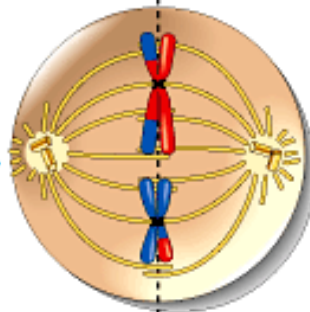


**Two haploid cells
form; chromosomes
are still double**



Sister chromatids
separate

**Haploid daughter
cells forming**



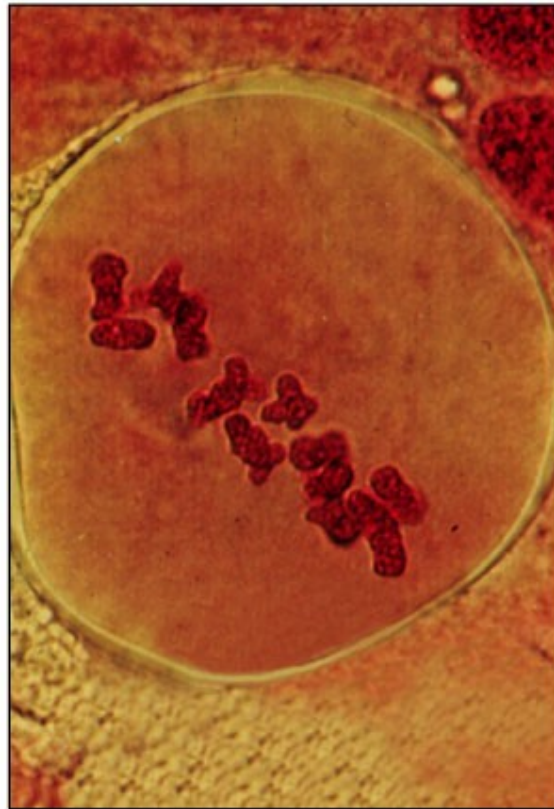
During another round of cell division, the sister chromatids finally separate; four haploid daughter cells result, containing single chromosomes

Meiosis 1

Prophase I



Metaphase I

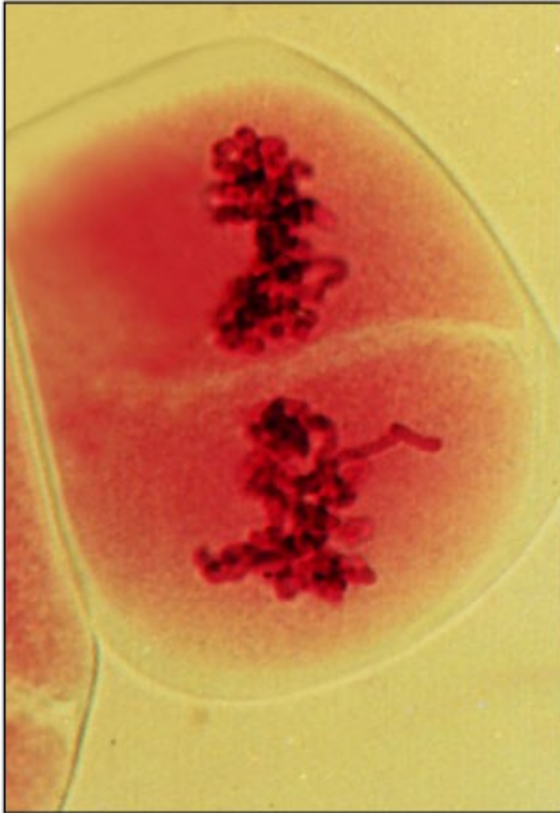


Anaphase I

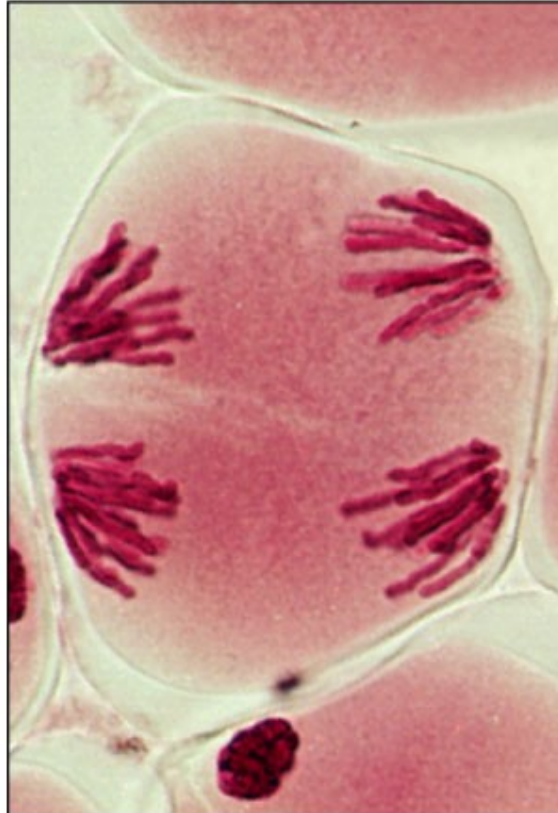


Meiosis 2

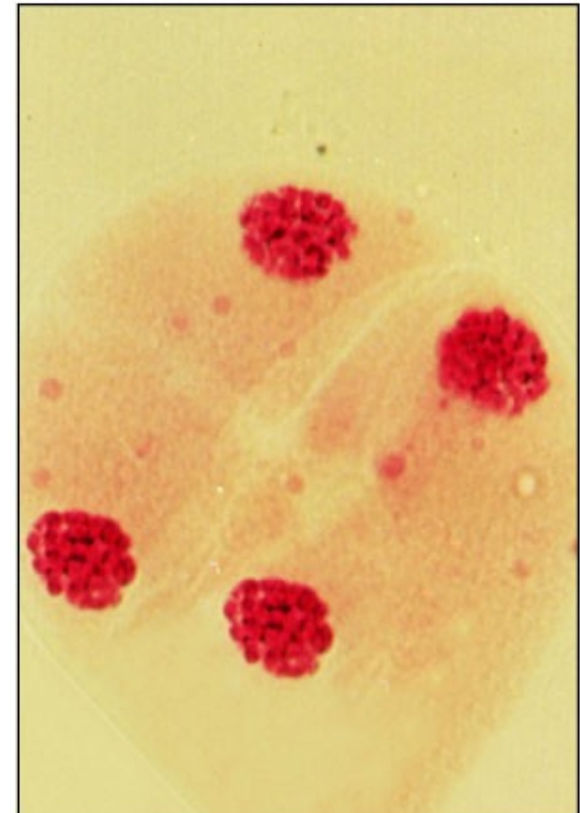
Metaphase II



Anaphase II

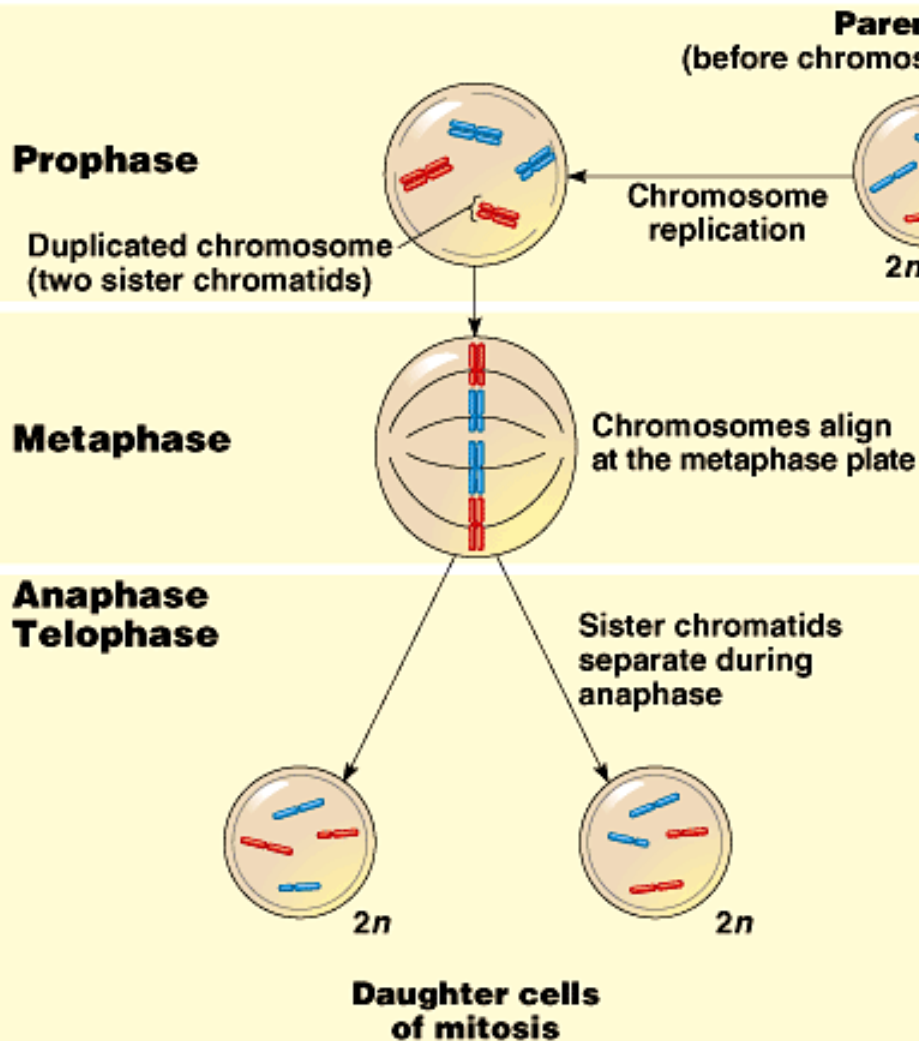


Telophase II

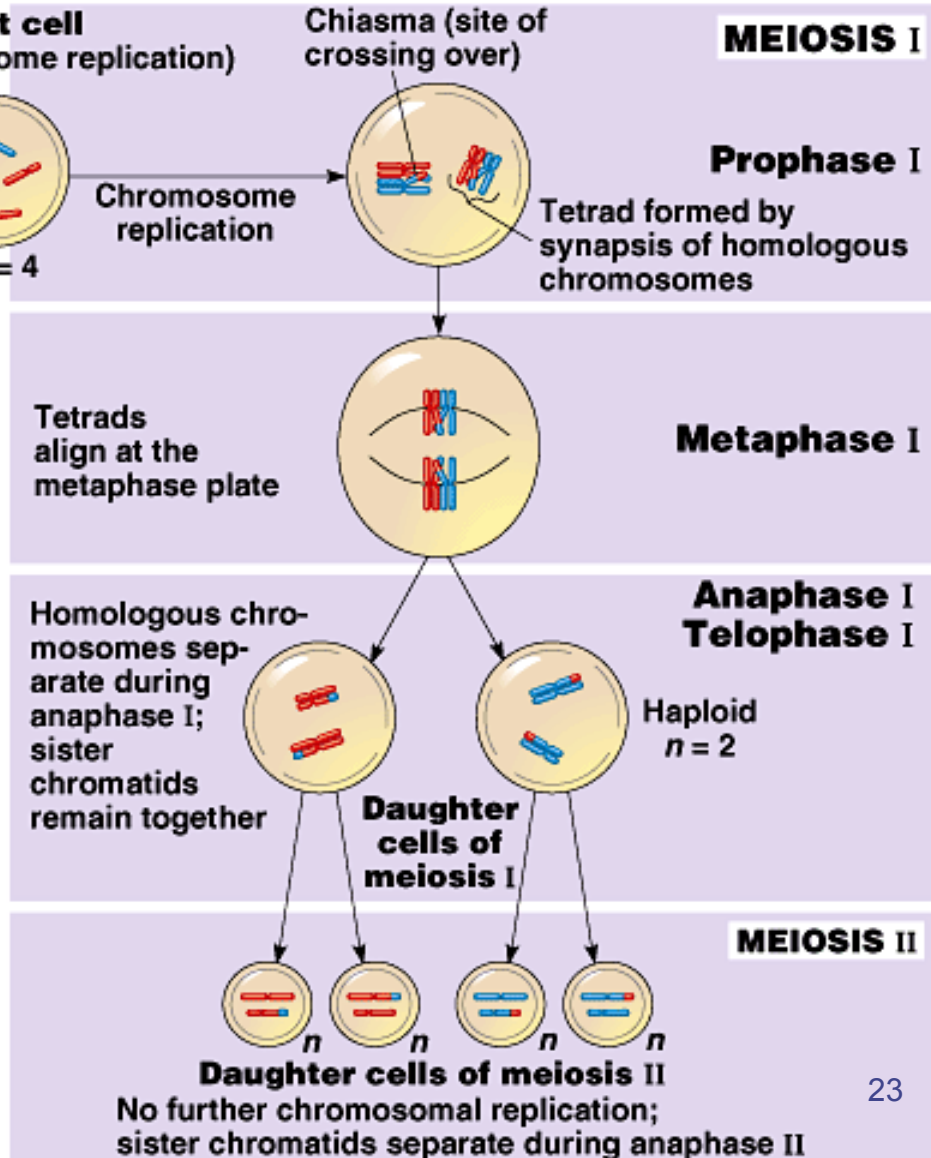


Mitosis vs. Meiosis

MITOSIS



MEIOSIS



Mitosis vs. Meiosis

■ Mitosis

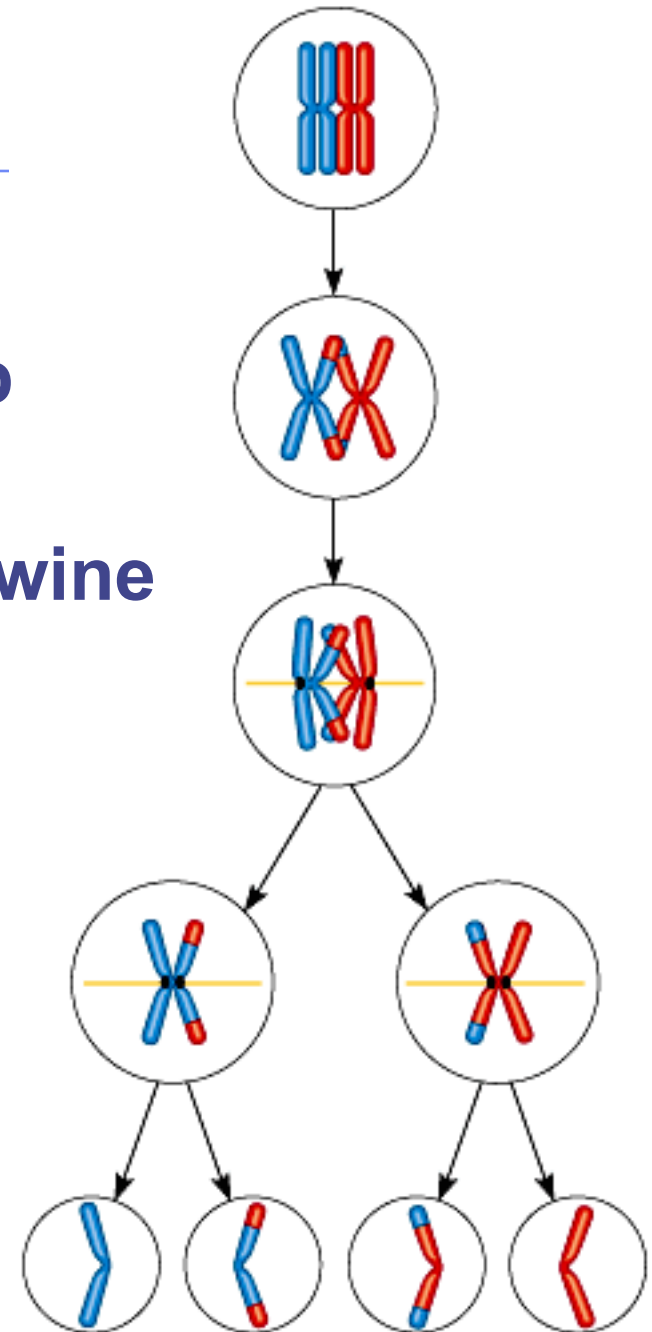
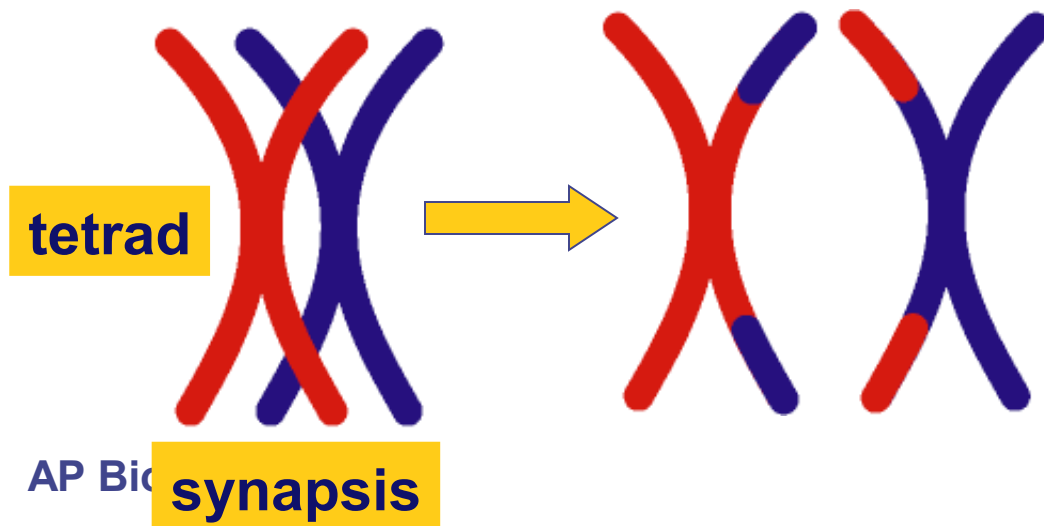
- ◆ **1** division
- ◆ daughter cells genetically identical to parent cell
- ◆ produces 2 cells
- ◆ $2n \rightarrow 2n$
- ◆ produces cells for growth & repair
- ◆ no crossing over

■ Meiosis

- ◆ **2** divisions
- ◆ daughter cells genetically different from parent
- ◆ produces 4 cells
- ◆ $2n \rightarrow 1n$
- ◆ produces gametes
- ◆ crossing over

Crossing over

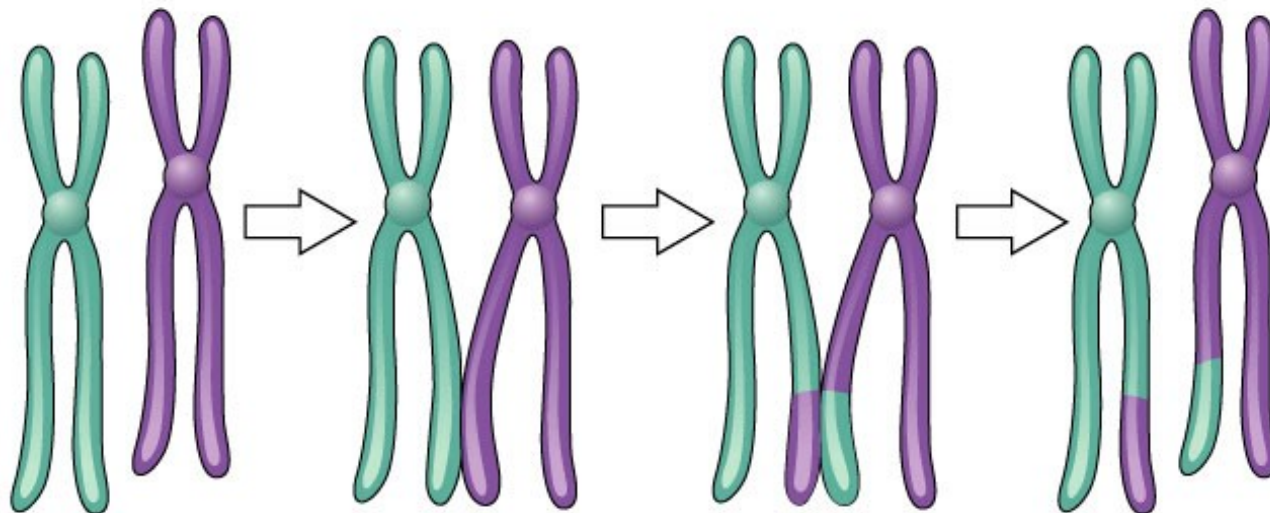
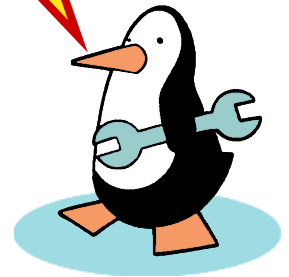
- During Prophase 1
 - ◆ homologous pairs swap pieces of chromosome
 - ◆ sister chromatids intertwine
 - ◆ crossing over



Crossing over

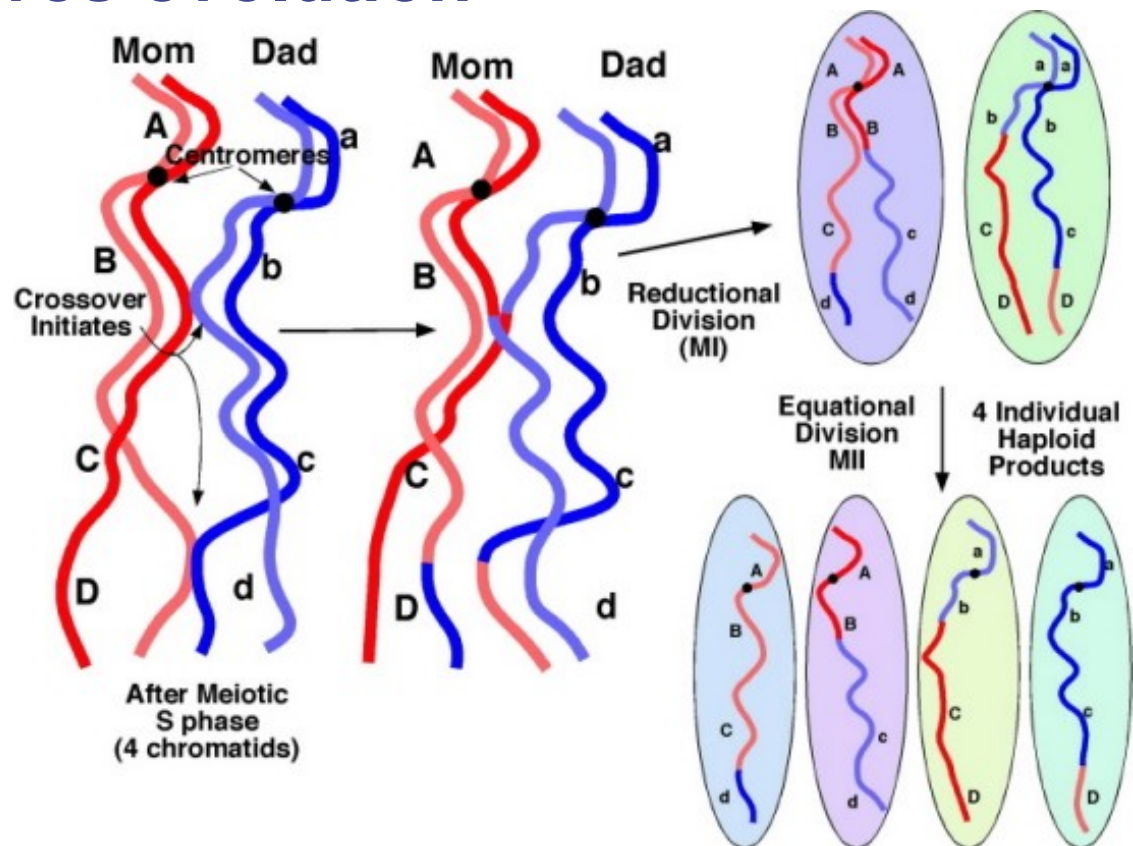
- 3 steps
 - ◆ cross over
 - ◆ breakage of DNA
 - ◆ re-fusing of DNA
- New combinations of traits

What are the advantages of sexual reproduction?



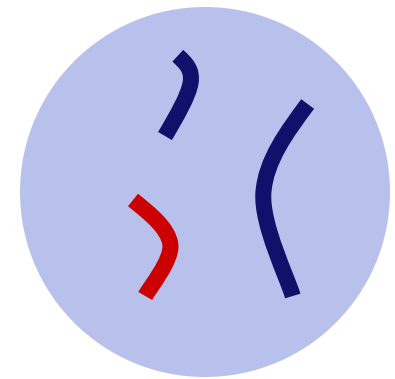
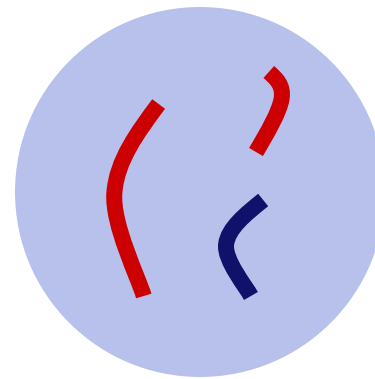
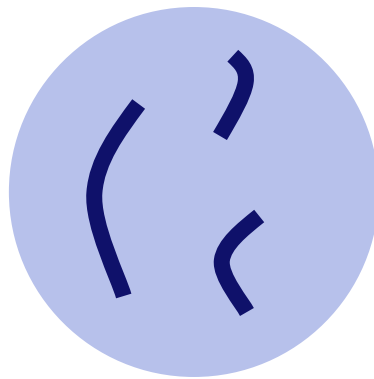
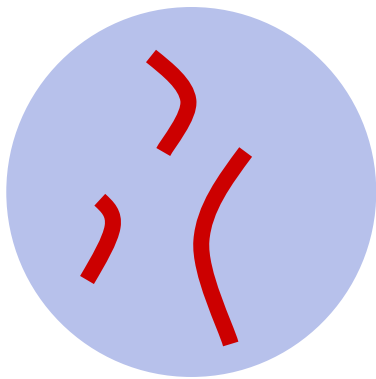
Genetic variation

- Meiosis & crossing over introduce great genetic variation to population
 - ◆ drives evolution



The value of meiosis

- Meiosis introduces genetic variation
 - ◆ gametes of offspring do not have same genes as gametes from parents
 - ◆ genetic recombination
 - random assortment in humans produces 2^{23} (8,388,608) different combinations



Al

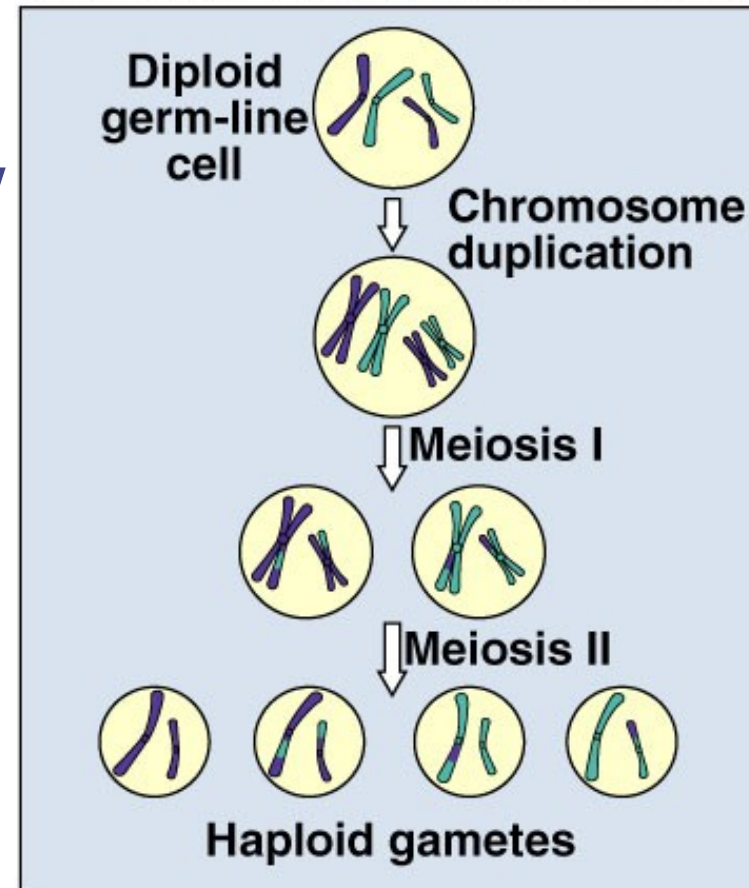
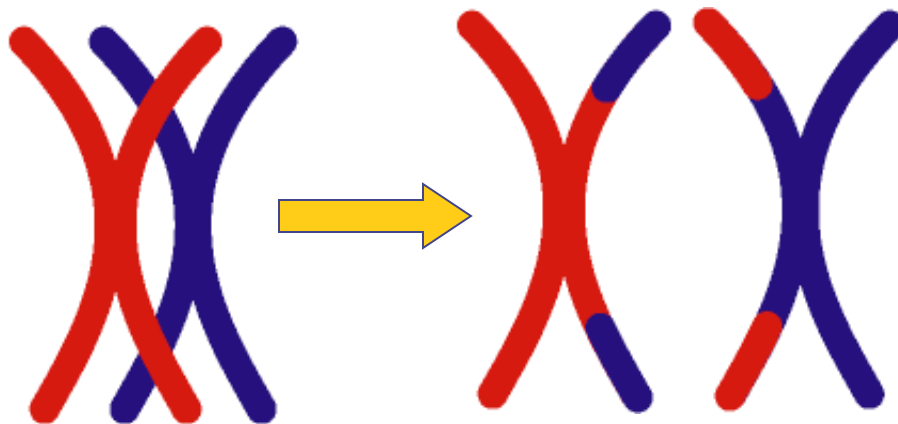
from Mom

from Dad

new gametes
made by offspring

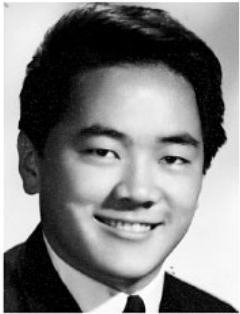
And more variation...

- **Crossing over**
 - ◆ creates completely new combinations of traits in next generation



Random fertilization

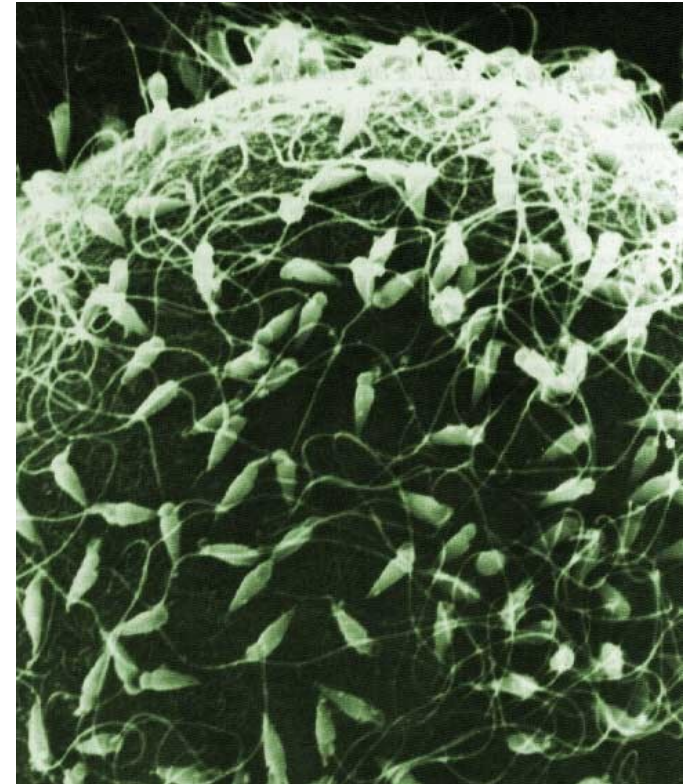
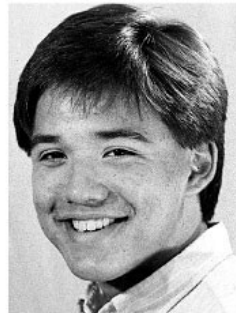
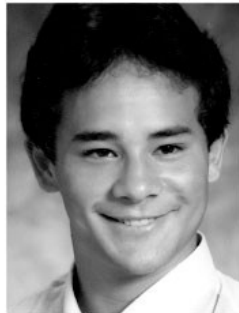
- Any 2 parents will produce a zygote with over 70 trillion ($2^{23} \times 2^{23}$) diploid combinations



Couple 1



Couple 2



Sources of genetic variability

■ Genetic variability in sexual reproduction

◆ independent assortment

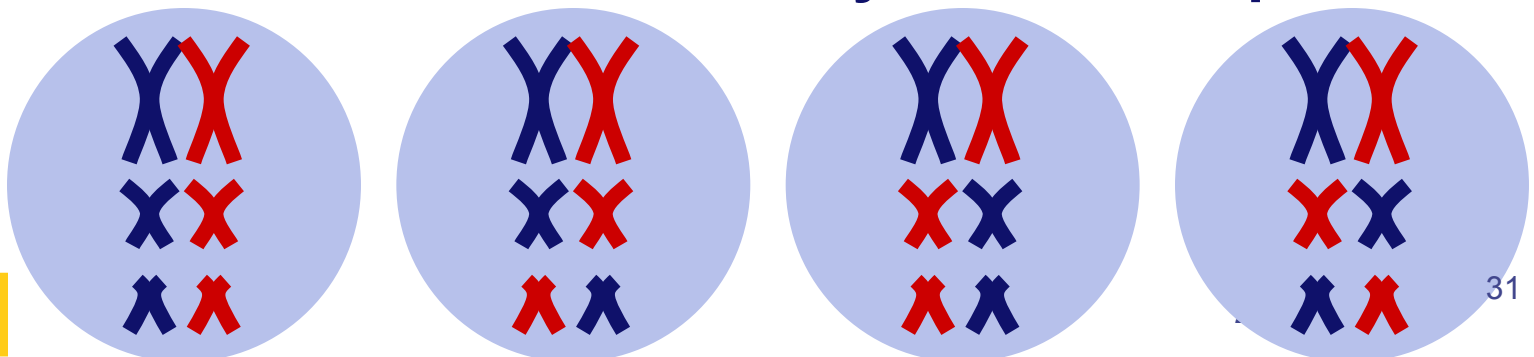
- homologous chromosomes in Meiosis 1

◆ crossing over

- between homologous chromosomes in prophase 1

◆ random fertilization

- random ovum fertilized by a random sperm



Sexual reproduction creates variability

Sexual reproduction allows us to maintain both genetic similarity & differences.

**Wayans
Brothers**



Baldwin brothers



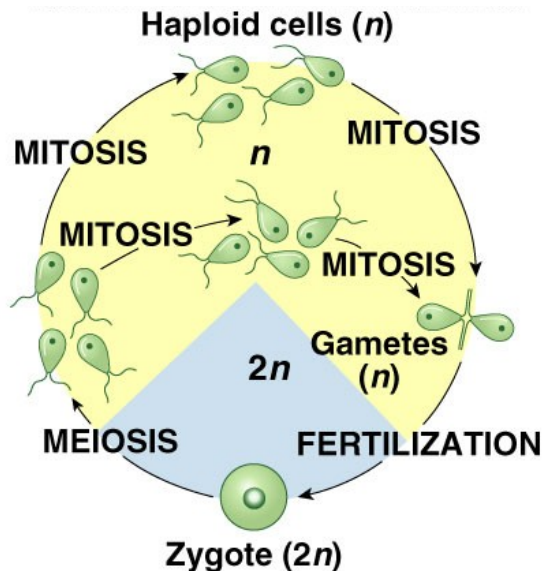
Martin & Charlie Sheen, Emilio Estevez



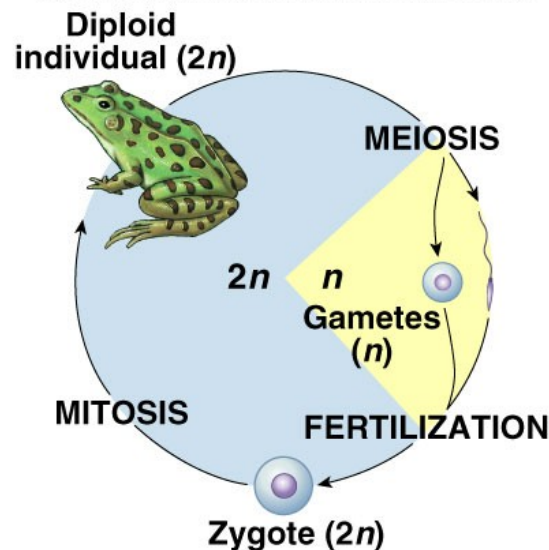
Michael & Kirk Douglas

Differences across kingdoms

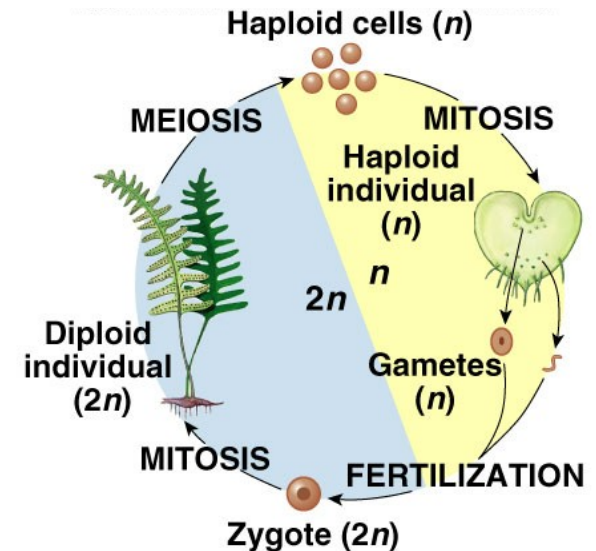
- Not all organisms use haploid & diploid stages in same way
 - ◆ which one is dominant ($2n$ or n) differs
 - ◆ but still alternate between haploid & diploid
 - have to for sexual reproduction



(a) Some types of algae



(b) Most animals



(c) Some plants and some algae

What are the
DISadvantages of
sexual reproduction?

Any Questions??

